STATUS OF THE ART IN SEA WATER DESALINATION

REVIEW OF TECHNOLOGIES

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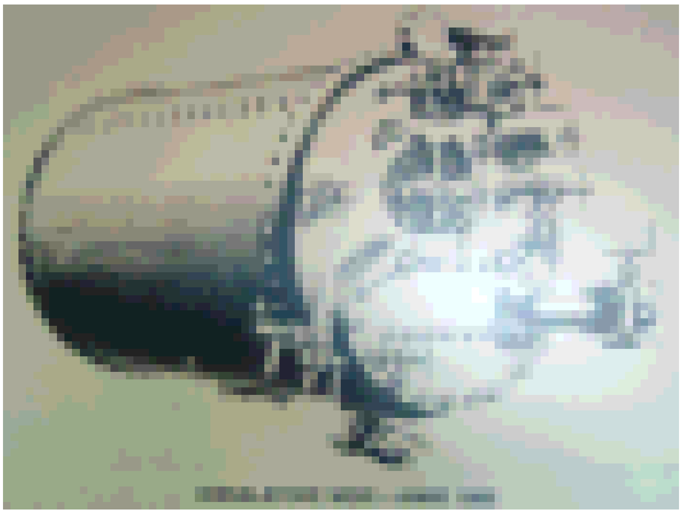
The production of fresh water by desalination of the seawater is a target of humanity since very ancient times. The solar evaporation technique was known and used by the Egyptians since 2000 BC. However the new era of industrial plants started in the end of the 19th century upon the request of the Royal British fleet to have its ships equipped with individual means of production of fresh water and accordingly to afford long navigation schedules without stopping in the ports.

Lord Weir studied and constructed the first series of seawater distillers, energised by the steam of the engine of the war ships.
The photographed prototype is dated 1885.
Since that time, the technology of distillation was continuously
Improved, and today is still one of the most used process for the
Industrial production of large flows of fresh water.



The second principle of thermodynamics clearly states that the reduction of the entropy content of a system requires a large amount of energy to be spent. The separation of salt from water therefore is to be an expensive process whichever technique shall be used. Different energies can be spent (thermal or electrical) and different efficiencies can be enjoyed according to the technological achievements, but cheap desalination cannot be made in any case.

1. MODERN DESALINATION PROCESSES

Many fundamental principles were studied and most of them abandoned (like freezing process). At the present time, two categories of process are industrially used and are in most cases in competition, namely the evaporative processes and the membrane processes.

1.1 EVAPORATION

This is the oldest process originated even before the diffusion of the electrical distribution. Thermal energy is easily available in large quantity and large production rates can be planned accordingly.
The modern techniques of evaporation and vapour demisting allow for the reduction of salinity by over 20,000-30,000 times and therefore these processes are specifically adequate to desalinate water with high salinity content and produce water of high purity.

Two main categories of evaporation processes are largely used, each with a number of variation and different details. The common principle is the evaporation of the seawater, the condensation of the vapor into fresh water and the recovery of the condensation heat for the economy of the operation.

1.1.1 MSF (Multi Stage Flash)

The condensation heat is recovered by heating the seawater, or the recirculating brine, with heat exchange taking place between a condensing vapour (fix temperature) and a liquid flow (temperature increasing during the exchange). The heated seawater, or brine, is flashed, thus generating the vapour to be condensed.

Different process and mechanical arrangement are used for the implementation of the heat exchange

1.1.1.1 Process: once through

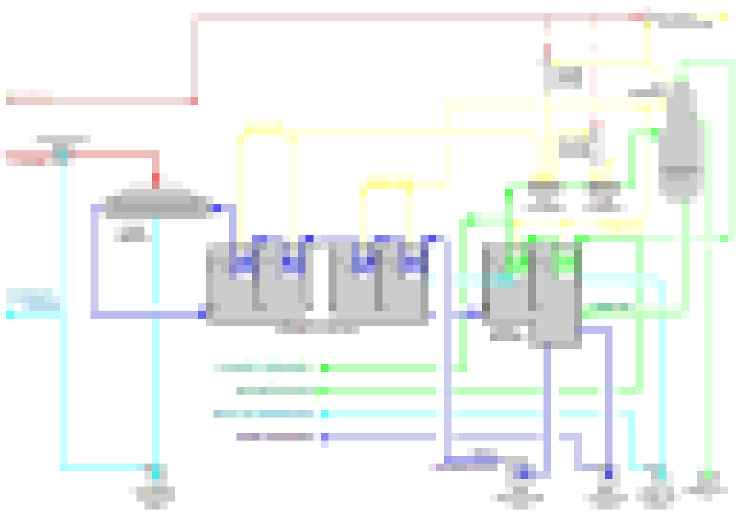
This process is rather diffused in some Asian countries like Indonesia because of its smaller construction cost and ease in running, in spite of the poor thermodynamic efficiency.

The cold seawater is pumped and flowed through the condensers of each stage. The temperature increases up to the last stage. An additional heating is provided by steam in the brine heater, and then the hot seawater is progressively flashed in the stages of the evaporator. The typical achieved GOR is approx. 6 (Gained Output Ratio is the mass ratio between the production and the steam consumption for the final heating),

1.1.1.2 Process: brine recirculation

This is the most diffused process mainly for the largest applications in the Middle East, because of the good efficiency (typical GOR Exceeds 8), in spite of its larger construction cost.

The cold seawater is used mainly for the rejection of the heat, as necessary to comply with the energy balance of the process. Only a part of it is added to the plant as make-up. The unflashed brine is recirculated in the condensers (tube side) thus enjoying the valuable residual temperature of the brine. The following simplified scheme is quite typical for this process.



1.1.1.3 Mechanical: cross tubes

In spite of its higher cost, this is the most diffused arrangement, because of the easier possibility of maintenance and cleaning the tubes when fouled or scaled.

Each condenser is located across the evaporator, such that two water boxes are exposed to opening and maintenance in each stage. The length of the tubes approximately equals the width of the evaporator. The number of condensers equals the number of the stages.

1.1.1.4 Mechanical: long tubes

This arrangement allows for smaller construction costs and therefore is often preferred in combination with the “Once Through” process for the cheapest installations. However the maintenance constraints are limiting the diffusion of this arrangement to only small size plants.

The tubes bundle is disposed longitudinally and services several stages. The length of the tubes equals the length of the evaporator. A limited number of condensers can be installed for a large number of stages and the number of water boxes is reduced accordingly. Typically 20 m tubes can service 5 or even more stages.

The combination of two main processes and two main mechanical arrangements provides four main types of MSF plants each of them available on the market and experimented in industrial installations. Moreover some other arrangements with innovative contents are now being studied and tested with good chances of future diffusions. Two of them are briefly mentioned hereunder:

1.1.1.5 LTF low temperature flash

This process was firstly tested in Italy by SOWIT and then in India in 2003/4 by NIOT in Chennai; and in both the occasions the results were very promising:

Whenever seawater is naturally available at two different temperatures, the warmer one can be cooled by flash down to an intermediate temperature and the vapour condensed by the colder flow. The difference in temperature has to be at least 6 °C and larger it is, more efficient desalination can be achieved. In this process, no consumption of energy is to be accounted, (besides the consumption of the auxiliary equipment) being the entirety of primary energy exploited from natural availability. SOWIT constructed a plant feeded by the warm seawater rejected in the cooling system of a power plant. NIOT tested the feeding of warm seawater collected from the surface of the sea, and the condensation with cold seawater collected from deep-sea bottom.

1.1.1.6 Distillate recirculation

This process is still in its preliminary study by SWS, but the forecast of simplification in operation and reduction in the costs is quite promising.

Instead of recirculating the brine as per process 1.1.1.2, the distillate can be recirculated ensuring similar thermodynamic efficiency, with remarkable advantages. The condensation can be made by contact, thus eliminating all the heat-exchanging surface in the condensers: Moreover the construction materials can be of lower grade, such as recirculating pump, piping and valves.

1.1.2 MED (Multiple Effect Distillation)

The heat recovered from the condensation is directly exchanged for the evaporation of the seawater. Compared to MSF, two main thermodynamic advantages are enjoyed. The heat transfer coefficient is higher, well exceeding 3000 Kw/m2°K, and the working difference in temperature is stable during the heat exchange, without the logarithmic effect in the calculation of the surface.
This process has been actually appreciated in the chemical industry of distillation since very long time ago. The successful application in seawater desalination is however as recent as from about 30 years, after solving the problem of controlling scaling.
The weak point of the process is that the seawater flows in thin film and slow velocity, outside the tubes and therefore no inspection nor maintenance can be easily made inside the bundle.
Because of its rather short life, no prevailing standardisation of the mechanical arrangement is still available for MED plants, and each designer is still proposing quite different sizes and shapes for the same performance,

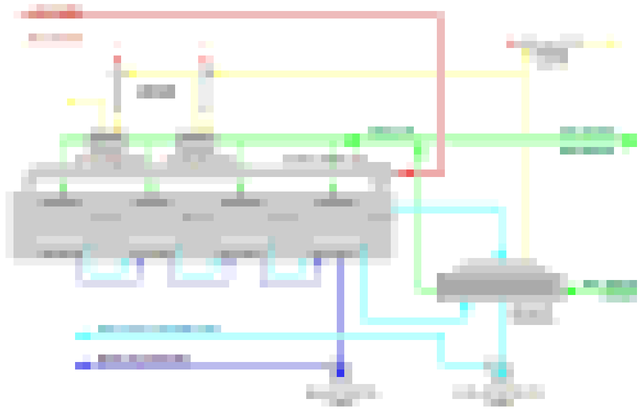
Three different process arrangements are however quite diffused and acknowledged as process categories:

1.1.2.1 Simple MED (or ONCE THROUGH VAPOR FLOW)

The feed steam is just cascaded from the first effect to the following down to the last one and then condensated. In each effect an amount of condensate is produced equal to the seam feed (less some losses due to dispersion and preheating of the sea water). This system is quite convenient for the consumption of low enthalpy steam or for the use of recovered heat, being the requested temperature of the primary steam not exceeding 70-75°C. These plants are often installed as replacement of the turbine condensers in the power plants, after the exploitation of the steam in the production of electricity down to nearly the condensation temperature. The achievement of high GOR however requires for a large number of effects (typically 9 effects for GOR 8), and therefore the plant size is quite large and expensive.

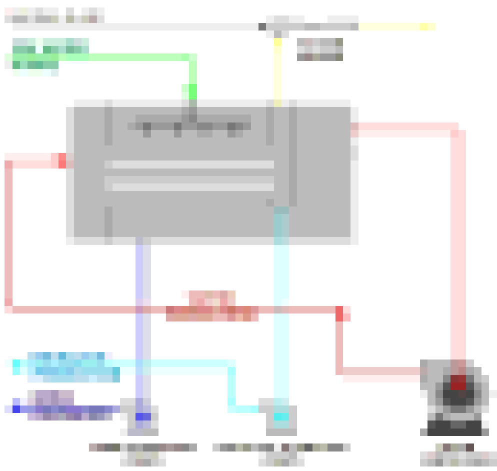
1.1.2.2 MED/TVC with Thermo Vapour Compression

Whenever available at least at 4 – 5 bar, the input steam can be used as motor steam in a steam ejector before feeding the evaporator. By this way, the temperature is reduced as necessary for the desalination requirement and at the same time a portion of the vapor produced in the coldest effect can be suctioned and recirculated in the first effect. Therefore the quantity of condensing steam is quite larger, being the sum of the feed steam and the recirculated vapour. The typical GOR 8 can be achieved with only 4 effects, thus reducing the dimension and the cost of the evaporator compared to simple MED 1.1.2.1.
This is probably the most diffused MED arrangement and the typical scheme is hereunder outlined:



1.1.2.3 MVC Mechanical Vapour Compression

The vapour produced in the last effect can be recirculated to the inlet of the evaporator also by a centrifugal compressor, as alternative to the thermocompressor described in para 1.1.2.2. This technology is quite diffused because the process can be operated also without any steam, just by recirculating the total amount of vapour to the inlet as outlined in the scheme hereunder



The limitation of this process is due to the dimension of the compressors available in the market with acceptable reliability: The capacity of 1500 t/d is now considered the limit according to the present status of the art.
The most efficient arrangement is consisting of a single effect, and the ratio between production and consumed power is ensured by the head of the compressor, typically in the range of 30 to 50 mbar. Higher is the head, higher is the available difference in temperature and smaller is the exchanging surface (also smaller are the investment costs) but higher is the power absorption.
MVC plants are normally preferred when no steam is available and small production of high quality distillate is requested.

1.2 MEMBRANES

Filtration on membranes is quite a new technology originated approximately 30 years ago and since then rapidly growing in reliability and diffusion.

The filtration on membranes ensures the reduction in the salinity in the range of approximately 100 times. Therefore its application is quite suitable whenever a low salinity water is to be desalinated (brackish Water) or whenever a poor quality fresh water is requested. Two passes on membranes can be designed whenever necessary, but in this case most of the advantage of the low cost is lost:

Many types of membranes are available in the market according to the requested performance such as for Reverse Osmosis (all ions are filtrated), nanofiltration (only bivalent ions are filtrated as applicable for softening), ultrafiltration (only large molecules are filtrated)

Two main categories of processes are classified in the Membrane Desalination namely Electrodialysis and Reverse Osmosis. The difference is in the type of force used to overcome the osmotic pressure and get the flow of fresh water against it.

1.2.1. EDY Electrodialysis

The force is provided by an electric field such to address positive and negative ions in the opposite sides of a cell, through membranes, and obtain fresh water in the middle section. This system is seldom appreciated in the industrial production of water and limited to rather small plants.

1.2.2. RO Reverse Osmosis

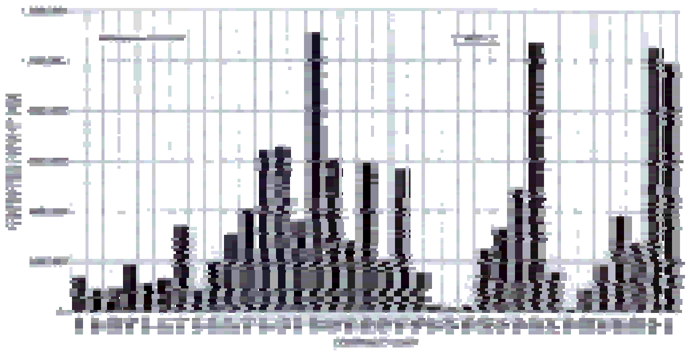
The force is provided as pressure by mechanical pumps. The pressure is to be higher than the natural osmotic pressure, that is a function of the salinity. For seawater the pressure is to be in the range of 70 bar, whilst it may be much lower in the case of brackish water. Therefore the convenience of the RO process is much enhanced whenever the raw water is brackish

The main inconveniences in RO may be originated by the turbidity of the raw water that is to be pre-treated up the max limpidity as appropriate to filtrate ions without being plugged by impurities. Another inconvenience is due to the local high concentration of salts on the membranes, pressed by the flow being filtrated, that may cause scaling. Additivation of chemicals and acidification is necessary in this respect.

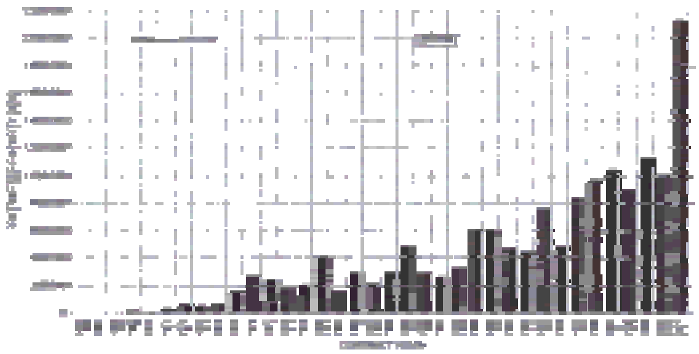
The RO process is much cheaper than any corresponding evaporation process and therefore it is rapidly diffusing in spite of its lower regularity and more accuracy requested in the operation and maintenance.
It can be roughly considered that a single pass plant shall cost 50% than a MED plant: Also the operation is quite less expensive, also because many devices are available to recover the energy from the pressurised residual raw water to be discharged. The most advanced techniques allow for the consumption of less than 5 kW/m3 and a water recovery ratio exceeding 35%.

2. COMPARISON OF TECHNOLOGIES AND PROCESSES

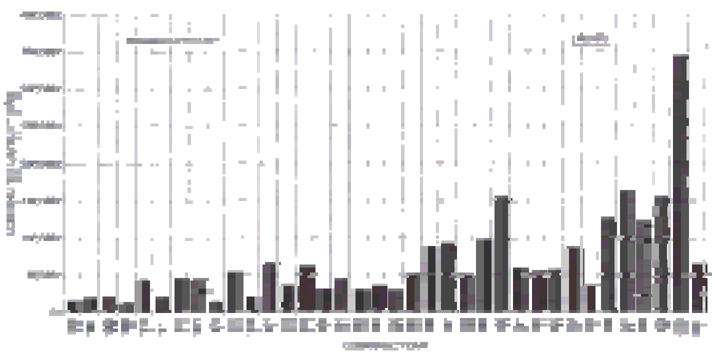
The choice of the most convenient technology and process for any specific application is quite an important topic. In the last years the parameters influencing the choice has been changing continuously, such to make any general conclusion very difficult.
These parameters are essentially the cost of investment and the running cost of the plant, each of them varying remarkably according to the cost of the materials, the cost of workmanship and the cost of the energy. All these costs and their ratio are changing year-by-year and differently country-by-country. Moreover the continuous technological progress and the technical achievements of the designers and constructors of the pants are changing the scenario quite dramatically. We hereby reproduce some statistical data of the yearly investments in desalination, classified by desalination process.



MSF PLANTS



R.O. PLANTS



MED PLANTS

In spite of these continuous variations, some general concepts can be focused in the competition among technologies, as outlined hereunder:

2.1. COMPETITION BETWEEN EVAPORATION AND MEMBRANES

This is the very hardest competition that involves different subjects. Membranes are studied, produced and sold by a limited number of large multinational chemical corporations. Investments in the development are huge and the technical achievements quite remarkable. Evaporation is studied by a limited numbers of scientific institutions and by very few international designers of rather small dimension and specialised capacity.

Membranes are undoubtfully convenient whenever the duty in salt reduction is lower, such as when the raw water is brackish or when the desalinated water is for agricultural or cheap potable use. Membranes are convenient also when energy is to be brought from far away and electricity is the most convenient mean.

Evaporation is more convenient when a convenient source of steam is available and when high purity distillate is requested. This requirement is normal for the industrial use of fresh water, such as make-up to boilers or severe process service. In some rich countries of the Middle East, MSF is preferred also for the production of high quality potable water. Having practically no residual sea water salts, the distillate can be remineralized according to any desired formula up to the composition of any high quality mineral water with calcium bicarbonates and no sodium chloride at all. This result is impossible by Reverse Osmosis because of the remarkable residual content of sodium and chlorides coming from the seawater.

The dimension of the plants was a limit for reverse osmosis since the end of 1990 years. However in the last years installations as large as 100,000 m3/d are becoming quite usual. In these cases anyway some unregularity is to be accepted because of the risk of statistical malfunction of few membranes among the very large number of installed ones.
The seasonal operation of the plant usually allows for proper time for maintenance.
Evaporation is more suitable for high regularity heavy duty operation

In most cases the installation of RO plants requires half of the investment than any evaporation plant. In some cases however the high turbidity of the raw water and the specification of the fresh water requires for large pre-treatment and after-treatment units that the investment cost can be equalised.

The energy consumption of RO is in the range of 25% of any equivalent evaporation, but electricity is requested, that can be produced with an efficiency of about 50% as achieved in Combined Cycles. Therefore the consumption of RO is still in the range of 50% than evaporation.
This is a topic of extreme importance because the cost of energy is the greatest part of the cost of desalinated water rated typically between 40%-50% of the total cost.
The value of energy however is not only depending on the quantity, but also on the quality. The enthalpy content of the steam requested for the evaporation can be very low, such to use the steam for expansion in a turbine first and for evaporation afterwards. In this case, only a portion of the cost of the steam can be debited to the desalination, thus inverting the energetical convenience considered above.

The ratio between investment cost and energy consumption is to be considered carefully case-by-case, according to the mortage plan and to the cost of the fuel prevailing at the time and in the place of the plant

2.2 EVAPORATION – COMPETITION BETWEEN MSF AND MED

MED can ensure the same capacity and the same efficiency of MSF with an investment as lower as 20%-30%. Therefore MED is replacing MSF in most of the applications. The limit of MED is in the size: being the total capacity splitted in a limited number of effects, each effect has a much higher capacity than each stage of the corresponding MSF. For the achievement of GOR 8, the MED/TVC arrangement requires 4 effects, whilst the typical MSF Brine Recirc requires 20 stages. In the last years a few MED/TVC plants of 20,000 m3/d were delivered, however the capacity of 10,000 m3/d is still considered a large capacity for this process.
The convenient applicability of MSF is therefore limited to huge installations above 10-20,000 m3/d. At the present time the maximum experimented capacity of MSF is close to 60,000 m3/d for each unit. Very few small MSF units are still requested by some clients who enjoy the similarity with previous existing plants or eventually some easier procedure in running and maintaining MSF than MED.

The running conditions of MSF are more severe for corrosion and scaling, being the TBT (Top Brine Temperature) as high as 100 to 115°C. The design and the arrangement of construction materials are well assessed and standardized after over 40 years of experience in industrial applications. The materials have to be of high grade and the construction codes have to be very severe.
The running conditions of MED, MED/TVC and MVC are quite more gentle, with the TBT not exceeding 60 to 70°C and with a negligible difference in pressure between tube side and shell side. Therefore lower grade materials and less severe construction codes can be appreciated in the design and construction of the plants, thus increasing the difference of costs even more, compared to MSF. The more recent diffusion of MED plants has not yet allowed for a standard to prevail, and each designer is following its own design criteria and standard. Moreover the larger quantity of applicable materials causes a remarkable difference in the realisation of similar plants
In other words:
For MSF plants, the client is supported by well assessed standards. For MED plants the client has to trust on the designer and relay on its recommendations and experience.

2.2.1 MSF - Competition among brine recirculation and once through

Brine Recirculation allows for much higher efficiency than Once Through and therefore it is easily prevailing in most applications. Whenever the requested GOR is not exceeding 6, Once Through may be considered for its lower cost (approx 20%). This case however happens very seldom.

2.2.2 MSF – Competition among cross tubes and long tubes

The long tubes arrangement is 10% cheaper than the cross tubes arrangement, however it is not very diffused because better applicable in medium and small size plants, when MSF is not prevailing against MED in any case.

Some difficulty may arise in cleaning the long tubes and in overcoming the problems of different elongation between the material of the shell and the material of the tubes.

2.2.3 MED – Competition among simple MED, TVC and MVC

TVC is the most diffused MED plant in direct competition with MSF as per paragraph 2.3, being feeded by the same type and quantity of steam. However this steam of at least 4 or 5 bar is still highly valued and the running cost can be considered expensive. Whenever LLP steam or recovery heat is available at low temperature, the simple MED is always convenient even if 20% more expensive than the corresponding TVC.

MVC has a limited field of applicability because of its limited dimension and demand of high value energy such as electricity. The absorbed power is typically from 9 to 14 kW/m3 i.e two to three times more than RO. The cost is rather high, in the range of 20%-30% higher that TVC. However it is preferred in many cases when very high purity water is to be produced with the maximum flexibility (30% to 100% of capacity) and maximum reliability (over 97% availability). The price of high quality distilled water well compensate for the high investment and high running costs.

The evaluation of convenience cannot be subject to any fix rules. However the concepts above are summarized in a table enclosed herewith, with the scope to provide general and preliminary guidelines for the selection of the technology.
The validity is subject to a large number of parameters depending on the market situation and on the sensibility of the client.

SWS	*Saline Water Specialists*	**Brief Manual for the choice of the most convenient Desalination Process**

Table of Ratings	**Membrane**	**Evaporative**				**Hybrid**
Process Versus Plant Feature	RO	MSF	MED	TVC	MVC	30% Evap -70% RO
1 Source of water						
1.1 Sea water	3	10	8	9	9	7
1.2 Brackish water	10	0	2	1	1	2
2 Product service						
2.1. Potable/Agricult	8	3	2	2	2	7
2.2 Process/Industr.	2	7	9	9	9	5
3 Site						
3.1 Remote	9	2	0	2	7	2
3.2 Close to Power Gen.	4	10	10	9	6	9
4 Service						
4.1 Heavy duty	3	10	9	9	7	9
4.2 Discontinuous	8	0	2	4	5	2
5 Cost of Energy						
5.1 Waste recovery	0	8	10	7	0	3
5.1 Low Cost	4	6	8	7	3	7
5.3 High Cost	9	4	6	6	2	8
6 Skill in Op/Maint						
6.1 High Skill	8	3	3	4	7	5
6.2 Low Skill	2	7	7	7	5	4
7 Investm Financ Facilities						
'7.1 Low Interests	3	8	7	7	9	4
7.2 High Interests	8	2	3	5	2	7
8 Production Rate						
8.1 Small up to 1000 t/d	10	0	6	7	8	2
8.2 Medium up to 10000 t/d	5	2	7	7	1	5
8.3 Large over 10000 t/d	2	9	2	3	0	8
TOTAL RATING						

Convenience is assessed for rating totalling over 50

Example 1						
1 Sea water	3	10	8	9	9	7
2 Potable	8	3	2	2	2	7
3 Close to Power Stn	4	10	10	9	6	9
4 Heavy Duty	3	10	9	9	7	9
5 Energy Low Cost	4	6	8	7	3	7
6 Low Skill	2	7	7	7	5	4
7 Low Interests	3	8	7	7	9	4
8 Medium size	5	2	7	7	1	5
Total	32	56	**58**	57	42	52
MED is recommended. However MSF and TVC are acceptable because rated well over 50						

Example 2						
1 Brackish water	10	0	2	1	1	2
2 Potable	8	3	2	2	2	7
3 Remote area	9	2	0	2	7	2
4 Discontinuous	8	0	2	3	4	1
5 Energy Low Cost	4	6	8	7	3	7
6 Low Skill	2	7	7	7	5	4
7 High Interests	8	2	3	5	2	6
8 Small size	10	0	6	7	8	2
Total	**59**	20	30	34	32	31
RO is the only recommended, being rated over 50						

Notice The ratings are evaluated on Oct 2005 and may be subject to review as per market changes

3 FORECASTS

The situation described in this paper is relevant to the end of the year 2004. However the situation of the technology is expected to vary in the next years as it happened in the past years, because of the continuous achievements made by the R&D activity.
Some forecast is possible by considering the remarkable efforts now in progress about each of the technologies, under the pressure of the global competition.

3.1 RO

Massive investments are still in progress by the producers of membranes with the target to reduce the power consumption by better suiting the models of membranes to the specific applications.
New producers are expecting to enter the market for general applications, thus reducing the selling prices.
RO is expected to increase its market share in the production of potable and agricultural water.

3.2 MSF

MSF is expected to progressively loose market shares against RO for large potable service and against MED for medium size industrial service. The technology is quite mature and no innovations in materials or specific equipments are expected. However some limited private investments are in progress for the review of the fundamental of the process. SWS is now studying the innovative Distillate recirculation arrangement, that may reduce the investment cost well below the corresponding MED/TVC.
Interesting tests are now in progress in UAE by LET (Egypt) for the improvement of MSF capacity by raising the top brine temp. from 115°C (usual) up to 150°C. The technique is based on the prevention of scaling by the initial nanofiltration of the make-up water and elimination of Ca^{++} ions. If successful this technique shall increase the production rate by 40% with a cost increase of approx. 20%, thus reducing the investment/m^3 by 20%.

3.3 MED

The technology is not yet mature and a large number of innovations are now being studied with the target to increase the quality of the distillate and to reduce the investment costs for the construction of the plants.
The investors in R&D are mostly the private companies. Among the most recent achievements, SWS recently patented the SED system that ensures a distillate as pure as only 0,1 ppm of residual salinity, adequate for direct feed to HP boilers without any further treatment.
Promising results are expected from the test of alternative materials for the heat exchanging tubes, such as silicon carbide or glass, instead of metals as titanium or aluminium and copper alloys. The means of fixing tubes of different nature are already available, as developed to prevent galvanic corrosion and are well applicable in the soft running conditions of the typical MED applications.
On their side, the fabricators of titanium tubes are engaged in reducing the cost of their tubes by reducing the available commercial thickness. In the last 10 years the thickness was reduced from 0,7 to 0,4mm and in the next 10 years the thickness is

expected to be reduced down to 0,2mm, according to the resistance of the material, as soon as the ability in forming thin tubes shall be achieved.

3.4 HYBRID PLANTS

For the production of potable water, the electrical absorption of R.O. is so much that a devoted power generation may be necessary. In this case the turbine condenser may be very well replaced by a simple MED plant working at approx 70 °C. Accordingly an additional production of fresh water become available in the typical ratio R.O. = 70-75%, MED = 25-30%.
Therefore the size of the power plant may be reduced down to 70-75%, as necessary for the only portion of production generated by R.O.. The economical advantage is quite remarkable, and additional advantages may be as well accounted, such as:

- Reduction of the seawater flow, being the same water used for cooling the MED and then feeded to the R.O.
- Improvement of the quality of the fresh water, as achieved after blending the production of R.O. and the production of MED. In some cases, the blending allows for R.O. in a single pass, with remarkable additional economical saving.

Very few hybrid plants were installed at Dec. 2004. However, the convenience is so large that a wide diffusion can be predicted in the next years.

3.5 COMBINATED PRODUCTION OF POWER AND WATER

The production of energy by combined cycle is suited to provide energy to the population, with good efficiency exceeding 50%. The condensation of the steam expanded in the turbine, at a T= 70 °C in a MED plant can provide approx 10 t/d of fresh water associated to 100 KWh/h. It can be noticed that the two production rates are well in tune to provide water and electricity in nearly the same ratio requested for the average need of the population.
Therefore it can be predicted that the production of water by evaporation can be associated to the generation of power whenever both these utilities are requested for the need of the population.
The overproduction of electricity in the night hours can be also used to run a R.O. train and store the water for blending with the continuous production of the MED evaporation.
The prediction is therefore for the most accurate optimization of the system power + water.

4 CONCLUSIONS

4.1 The dramatical recent increase of the cost of energy, forces the designers of desalination plant to devote the maximum concern to he overall limitation of the energy demand. In the past, the local availability of gas was considered a cheap source of energy in many countries producers of oil. However the diffusion of gas export facilities (gasline and LNG plants) are adding value to the gas, and its consumption is now to be carefully evaluated. Therefore any system feeded by waste energy shall be preferred in any country:
Hybrid plants (as per para 3.4) and turbine condensation
MED trains (as per para 3.3) are expected to expand their applications
RO, even when requiring small quantities of high value power, shall be preferred in all cases when the production of electricity is requested to fluctuate during the day (daily and night hours). The factor of operation of the power plant is not optimized in that case, unless the excess of energy is used to produce goods that can be stored.
This is the case of osmotic water that can be produced in night hours by the excess of electricity and stored in daily tanks.

4.2 The progressive specialization of the desalination plants shall increase the difference among the design of the plants suited for different services of the fresh water.

- For potable services, the cost of water is the main topic and the plant arrangement shall be designed and operated accordingly, as extensively outlined in this paper, and in para 5.1 hereabove.
- For industrial services. The regularity of the production and the quality of the water are the main topics.
  The chemical purity of TDS < 0.1 ppm was recently achieved by SWS with its patented SED system.
  The proper design can ensure the necessary regularity with no need to pay for the installation of spare units (as now often requested by many clients).

4.3 The diffusion of the desalination plants shall be enhanced by the proper suiting of the design, such to enable the growing countries to fabricate and operate the desalination plants with local workmanship and industrial capacity.

4.3.1 The design of R.O. plants and the assembly can be well afforded by many growing countries. However the proper operation requires a high level chemical skill, and the business of the membranes shall remain in the hands of a few multinational corporate, at both the time of the first installation and of the replacement.

4.3.2 The evaporative plants are now designed in the way to require high fabrication skill and expensive materials, such to discourage many growing countries from being involved in the fabrication.
However the conceptual design could be revised and allow more friendly and cheap materials such as concrete (for the shell) or painted carbon steel, that are very well suitable for sea water service, even better that S.S. 316 L